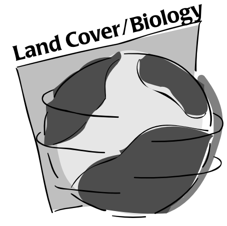
Introduction



The Big Picture

Earth's surface is two-thirds water. The continents on which we live make up the remainder. Until the launch of the first humans into space, we did not fully appreciate the beauty and diversity of our planet. We rely on Earth's surface (and a little bit above and below) to supply most of what we need to live. Therefore, mapping and monitoring this surface is critical to our wise use and protection of it.

Remote sensing simply means learning something about an object without making direct contact with it. We use remote sensing every day by hearing, smelling, and seeing. Historically we have used aerial photographs taken from balloons, airplanes, and more recently, digital images acquired by orbiting satellites, to map and monitor Earth's land cover.

Remote sensing from space has the great advantages of being able to cover very large areas quickly and to revisit the same area frequently. However, some of the detail that can be seen at ground level may not be detected by a remote sensing system. Therefore, it is beneficial to collect data at sample sites on the ground to accompany remotely sensed data about an area. It is not possible to effectively visit every place on Earth to map the land cover. Instead, we rely on samples – actual ground visits – and relate these samples to what we can see using various remote sensing systems.

Remote sensing observations of the land surface are usually presented as digital images. Each element of such an image is a *pixel* or picture element. The size of the pixels depends on the spatial resolution of the remote sensing instrument. Spatial resolution refers to the size of the smallest object or area that can be distinguished from its surroundings. The Landsat Thematic Mapper (TM) imagery used in the GLOBE Program has a spatial resolution or pixel size of 30 m x 30 m. See Figure LAND-I-1.

Spectral resolution refers to the wavelengths of light, commonly called bands, the satellite image sensors are capable of measuring. Our eyes also sense different wavelengths of light (colors), but we only see in a range of wavelengths known as the visible portion of the spectrum. The new Landsat 7 Enhanced Thematic Mapper is capable of sensing six bands – blue, green, red, near infrared and two mid-infrared, – at 30 m x 30 m spatial resolution. It also senses one band in the thermal infrared at 60 m x 60 m spatial resolution and one panchromatic band covering wavelengths from blue to near infrared at 15 m x 15 m spatial resolution. In GLOBE, we make use of five of the first six bands, which are the same as those available from earlier Thematic Mapper instruments. For more information on remote sensing, refer to the *Remote Sensing* section of the *Implementation Guide.*

Remote sensing scientists use satellite images as tools to help make maps of land cover types. An important issue that arises is, "How good are the land cover maps made from remotely sensed data?" The way to answer this question is to conduct an accuracy assessment of the remotely sensed map. If appropriate sample land cover sites are visited on the ground, then these samples can be compared to the same areas on the map and a measure of map accuracy determined. In this way, we can evaluate how good our land cover maps are. This assessment is very useful when it comes to making important decisions about Earth's land cover from these maps.

Finally, it is important that the ground samples and the remote sensing maps use the same classification system. A classification system consists of a list of labels or land cover types and the corresponding definitions for each label. Since the GLOBE Program is a world-wide effort, it is important that the classification system chosen be appropriate for any place on Earth. In the GLOBE Program, we have modified a widely accepted system developed by UNESCO (United Nations Educational, Scientific and Cultural Organization) to include both natural and developed land cover. This system is called the Modified UNESCO Classification (MUC) System. Everyone in the GLOBE Program uses MUC to label sample sites visited on the ground as well as the maps made from the remotely sensed data. Therefore, a consistent and uniform land cover map can be created for the entire world and validated.

Why Investigate Land Cover?

Land cover is a general term used to describe what is on the ground or covering the land. Different land cover terms are used to describe the differences we see when we look at the land. Land cover can include where we live (in houses or apartments), where we do business and produce goods and services (commercial and agriculture areas) and how we travel (on roads, trains, and from airports). It is also a term that is used to describe different natural habitats; desert, forest, woodland, wetland, glaciers and water bodies, among others. All living things depend on their habitat, their land cover, for survival. They find shelter there, they find food there, and they find protection there. Land cover has a direct effect on the kinds of animals that will likely inhabit an area. Therefore, land cover is of great interest to ecologists, who study how plants and animals relate to their environment.

Land cover can influence weather, soil properties, and water chemistry. Different land cover types are all distinct in their effects on the flow of energy, water and various chemicals between the air and surface soil. Natural land cover, meaning land cover that is not the result of human activity, is often an indication of the climate of an area. For instance, forests may be found on the wet side of a mountain while in the rain shadow on the other side there may be shrubland. In a coastal region with frequent fog, the plants that grow there modify the soil over time. The land cover in such an area is a community of trees, shrubs, and other plants indicative of a foggy coast. Large rainforests actually create their own weather with daily rain showers. In deserts, plants adapted to dry conditions dominate the land cover.

Knowing the type of land cover in a region helps us understand the local climate. For scientists studying atmosphere, soil and hydrology, the type of land cover surrounding measurement sites is an important piece of information. This type of information is often referred to as *metadata* and helps provide a context for evaluating data collected by the scientists or students on that site. However, for land cover scientists, land cover data provide much more than that.

Mapping

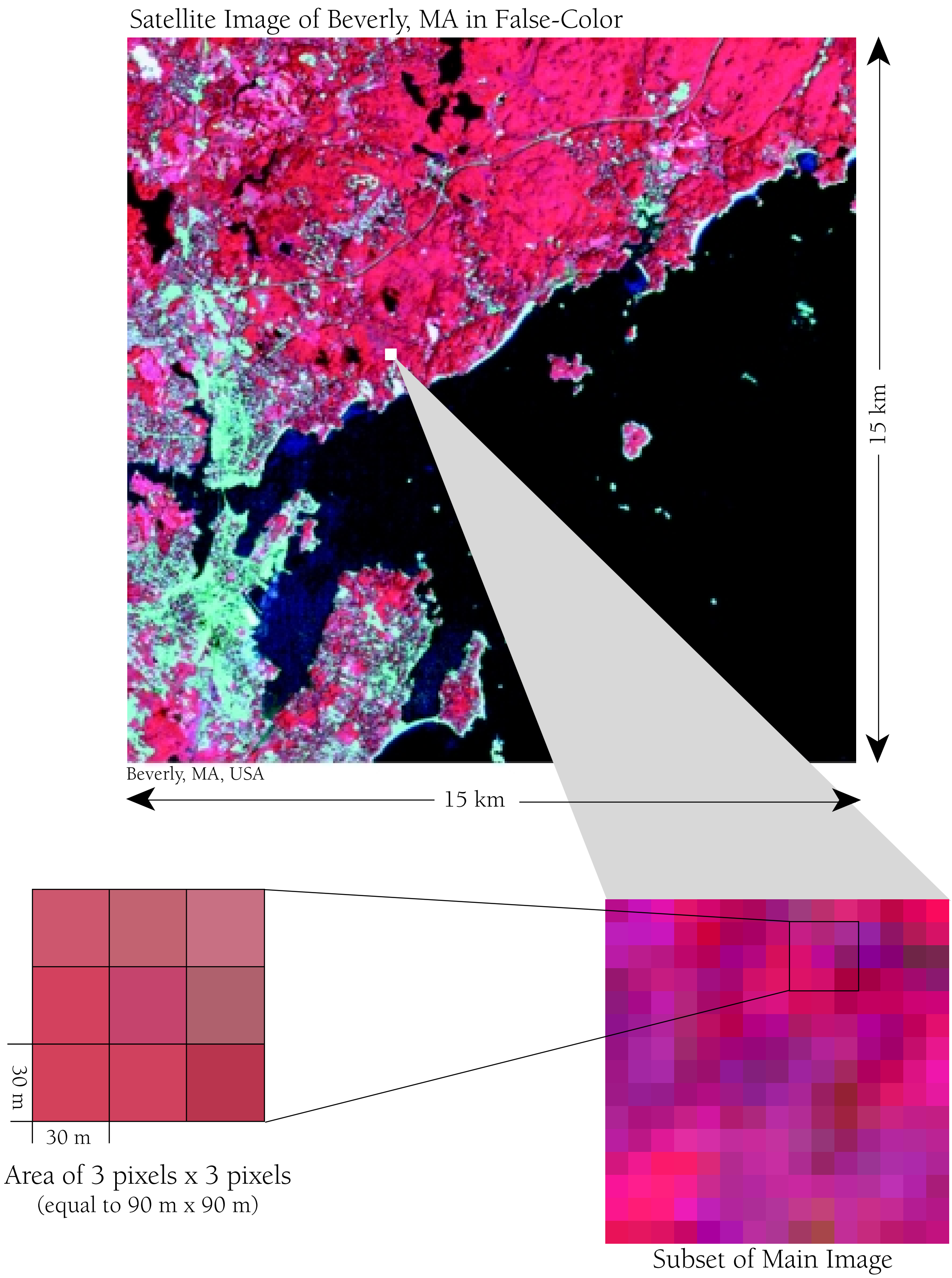
Data collected at land cover sample sites visited on the ground help land cover scientists to create and label land cover maps produced from satellite images and aerial photographs. Additional independent ground sample sites help verify how accurate these maps are. Data from ground sample sites such as detailed biometric observations (measurements of living things) help Earth systems scientists improve their ability to interpret satellite imagery.

Monitoring

Land cover maps are used to monitor endangered plants, animals and habitats, economic development, land use, fire fuel management, cropland management, wetland loss, effects of environmental change in ecosystems and other changes in land cover over time. The list of uses is long once scientists have access to accurate and precise land cover data.

Biometry data collected in the field assist scientists in monitoring the amount of nutrients, water and gases in vegetation. This is helpful in understanding Earth systems, including; nutrient cycles, the energy cycle and the hydrological cycle. Land cover influences these cycles in a variety of ways. One example is how solar radiation, reflected by land and vegetation, affects regional and global climate patterns. Since land cover is a component of numerous systems, monitoring its characteristics will provide more information for understanding global ecological systems. Plants are part of nutrient cycles and hydrological cycles and they can be used as indicators to monitor changes in these systems. Remotely sensed data that discriminate between various kinds of vegetation may be used to determine health and density of plants, but require ground observations to quantify and calibrate these relationships.

Figure LAND-I-1: Example Satellite Image



As you zoom in on a 15 km x 15 km satellite image, the pixels (which are 30 m x 30 m in size) become visible. In the *Land Cover/Biology Investigation,* students take field measurements at sites that are 90 m x 90 m (equal to 3 pixels x 3 pixels).

Scientists Need GLOBE Data

Scientists collect ground data to learn as much about Earth as they can. Ideally, Earth systems scientists would like to have information about every place on our planet. The more ground data the better. Practically, it is only possible to collect this information for a small sample of areas. Remote sensing provides a means of relating observations and measurements on the ground to the larger regional and global views. Ground data are needed to learn about sample areas and to validate (i.e., compare with) the maps generated from remotely sensed data. At a GLOBE school, students can significantly add to our limited supply of ground information. No other group in the world is collecting a uniform data set such as this. Therefore, GLOBE schools are providing unique, valuable information that will help scientists to better understand Earth. Through the *Land Cover/Biology Investigation Mapping* and *Data Collection Protocols,* GLOBE students will significantly help Earth systems science while increasing their own knowledge and understanding of the scientific process, ecological systems and their surrounding landscape.

Educational Objectives

Students participating in the activities presented in this chapter should gain scientific inquiry abilities and understanding of a number of scientific concepts. These abilities include the use of a variety of specific instruments and techniques to take measurements and analyze the resulting data along with general approaches to inquiry. The Scientific Inquiry Abilities listed in the grey box are based on the assumption that the teacher has completed the protocol including the Looking At the Data section. If this section is not used, not all of the Inquiry Abilities will be covered. The Science Concepts included are outlined in the United States National Science Education Standards as recommended by the US National Research Council and include those for Earth and Space Science, Physical Science, and Life Science. The Geography Concepts are taken from the National Geography Standards prepared by the National Education Standards Project. Additional Enrichment Concepts specific to the land cover measurements and mapping have been included as well. The gray box at the beginning of each protocol or learning activity gives the key scientific concepts and scientific inquiry abilities covered. The following tables provide a summary indicating which concepts and abilities are covered in which protocols or learning activities.

	Basic Protocols		
National Science Education Standards	Sample Site	Biometry	Manual Map.
Physical Science Concepts			
Properties of Objects and Material (K–4)			
Objects have observable properties	■	■	
Position and Motion of Objects (K–4)			
Position of objects can be described by locating it relative to another object	■		
Life Science Concepts			
The Characteristics of Organisms (K–4)			
Earth has many different environments that support different combinations of organisms	■	■	
Organisms and their Environments (K–4)			
Organisms' functions relate to their environment			
Organisms change the environment in which they live		■	
Humans can change natural environments			
Structure and Function of Living Systems (5–8)			
Ecosystems demonstrate the complementarity nature of structure and functio			
Regulation and Behavior (5–8)			
All organisms must be able to obtain and use resources while living in a constantly changing environment			
Populations and Ecosystems (5–8)			
All populations living together and the physical factors with which they interact constitute an ecosystem	■	■	
The Interdependence of Organisms (9–12)			
Humans can change ecosystem balance			
Geography Concepts			
How to Use Maps (real and imaginary (K–4))	■		
The Physical Characteristics of Place (K–4)	■	■	
The Characteristics and Spatial Distribution of Ecosystems (K–12)	■	■	■
How humans modify the environment			■

Advanced Protocols		Learning Activities						
Computer-Aided Mapping	Land Cover Change	Getting to Know	Site Seeing	Leaf Classification	Odyssey	Bird Beak Accuracy	Discovery Area	Using GLOBE Data
				■		■		
	■		■				■	
	■					■		
	■	■						
							■	
	■							
■	■		■		■			■
	■						■	
	■	■	■		■			■
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■	■	■	■		■			■
■	■		■		■		■	■

	Basic Protocols		
National Science Inquiry Standards	Sample Site	Biometry	Manual Mapping
General Scientific Inquiry Abilities			
Use appropriate tools and techniques			
Construct a scientific instrument or model			
Identify answerable questions	■	■	■
Design and conduct scientific investigations	■	■	■
Use appropriate mathematics to analyze data	■	■	■
Develop descriptions and explanations using evidence	■	■	■
Recognize and analyze alternative explanations	■	■	■
Communicate procedures and explanations	■	■	■
Specific Scientific Inquiry Abilities			
Use appropriate field instruments and techniques to gather Land Cover sample	■		
Make observations in order to determine the appropriate land cover type	■		
Communicate the results of land cover classification to reach a consensus	■		
Identify biometry measurements needed for MUC		■	
Use vegetation field guides to identify vegetation and species		■	
Interpret data to propose MUC classification		■	
Classify land cover and create a land cover type map			■
Evaluate how accurate the land cover map type is using accuracy assessment			■
Use land cover data and appropriate tools and technology to interpret change			
Gathering spatial data and historical data to determine validity of change hypotheses			
Use maps, aerial photographs and other tools and techniques on order to create a land cover map			
Recognize and analyze differing viewpoints on land cover classification and reach a consensus			
Integrate data from variety of different data sets to gain dynamic understanding of how earth system works			
Classification helps organize and understand the natural world			
A classification system is a system of labels and rules used to sort objects			
A hierarchical system has multiple levels of increasing detail			
Observe a landscape and design a model of it			
Draw a landscape from various perspectives			
Use different scales to view a group of objects			
Identify decision criteria for a classification system, and use it to classify birds			
Collect and interpret validations data			
Use numerical data for in describing and comparing the accuracy of the classification			
Use the land cover type map to discuss how a structure will affect organisms using a particular land cover type			
Analyze different scenarios that change the land cover types of an area			
Evaluate different solutions to various scenarios			
Use GLOBE Website to gather, analyze and interpret data			

Adv. Protocols		Learning Activities						
Computer-Aided Mapping	Land Cover Change	Getting to Know	Site Seeing	Leaf Classifi-cation	Odyssey	Bird Beak Activity	Discovery Area	Using GLOBE Data
■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■
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Measurement Logistics

Overview

This Investigation will involve studying the land cover in your GLOBE Study Site, a 15 km by 15 km area centered around your school. Within this Study Site, you will visit various Land Cover Sample Sites to collect data about the type of land cover present. Each of these Sample Sites must be 90 m X 90 m in size and have the same land cover type throughout. GLOBE provides the imagery of your Study Site. As you build an understanding of the land cover in your area, you will create a land cover type map from the satellite imagery. Ultimately, changes over time in land cover are studied through a comparison of two co-registered satellite images of your GLOBE Study Site and the accompanying ground measurement data that you have collected. The images are acquired a few years apart and you can compare the changes that occur between the two dates.

Where are measurements taken?

Your *Land Cover/Biology Investigation* measurements are taken in your GLOBE Study Site. This is the 15 km x 15 km area, with your school near the center, defined by the Landsat Thematic Mapper (TM) satellite imagery provided to you by GLOBE. For information on obtaining this imagery, contact your Country Coordinator, US Partner, or the GLOBE Help Desk. By performing the protocols and learning activities associated with this investigation, you and your students will become intimately familiar with this part of our global environment. Together, you will create and validate a land cover type map of this area.

Within your GLOBE Study Site, it is important that you select appropriate ground sites (called Land Cover Sample Sites) for observation and detailed measurements. See Figure LAND-I-1. You should have at least one Land Cover Sample Site for every type of land cover that exists in your Study Site. These Sample Sites are areas of homogeneous land cover (the same land cover type throughout) at least 90 m x 90 m in size. If you are in an area of homogeneous land cover that is larger than 90 m x 90 m, locate your Sample Site toward the center of the area. See Figure LAND-I-2. A Sample Site area of 90 m x 90 m is necessary in order to accurately locate the site on the ground and on the satellite imagery. This area is equivalent to 9 Landsat Thematic Mapper (TM) pixels (a square of 3 pixels by 3 pixels). See the *Remote Sensing* section of the *Implementation Guide*.

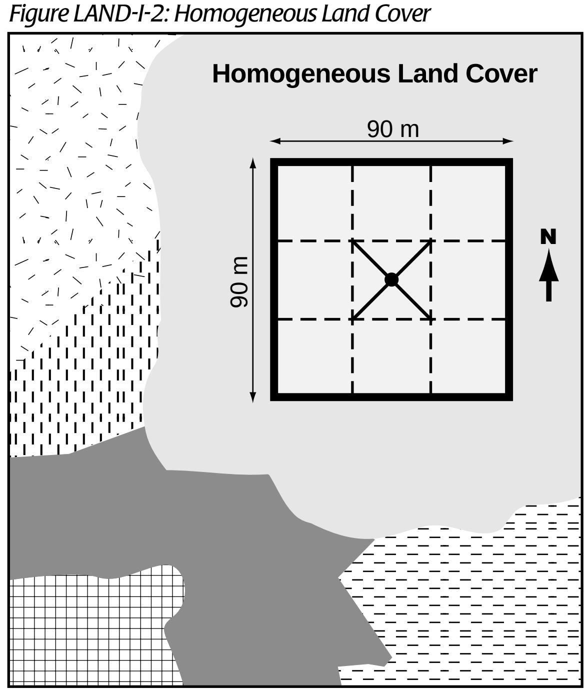
You may collect data from areas outside your GLOBE Study Site as well. For instance, some schools make periodic visits to remote natural sites such as national parks. They collect data while on these field trips and report their measurements to GLOBE. If your school will make repeated visits to such a remote location, you should request Landsat image products for this site from GLOBE so that you can do all aspects of the *Land Cover/Biology Investigation* for this additional area.

What measurements are taken?

There are two varieties of land cover measurements reported to GLOBE. The first involve observations taken at each of your Land Cover Sample Sites. The second involve land cover type maps that you make of your GLOBE Study Site.

The *Land Cover Sample Site Protocol* details the steps for taking measurements at a Land Cover Sample Site. There are three essential observations:

Figure LAND-I-2: Homogeneous Land Cover



- Latitude, longitude and elevation using a GPS (Global Positioning System) receiver.
- Land cover classification (using the MUC System, GLOBE's land cover classification system).
- Photographs taken in the four cardinal directions (N, S, W, and E) from the center of the site.

To determine the land cover classification you may need to take additional measurements. The amount of measurements will vary depending on the nature of the land cover at the site. Classifying a site can take from 20 minutes to approximately an hour, depending on which measurements you must take. In addition to the measurements from the *Land Cover Sample Site Protocol*, you may include quantitative measurements of the mass of plant matter present, known as biometry measurements. The *Biometry Protocol* outlines the steps to take these measurements, which include canopy and ground cover, tree, shrub and/or graminoid height, tree circumference and graminoid biomass. **All relevant Biometry measurements should be taken in order to determine and/or verify the correct land cover class.** These measurements are used to study vegetation growth and change. Throughout your investigation, you will collect and report data from a variety of Sample Sites.

As part of the *Land Cover/Biology Investigation,* you will also generate land cover maps of your Study Site. You will create a map of land cover type either by hand following the *Manual Land Cover Mapping Protocol* or through the use of MultiSpec software following the *Computer-aided Land Cover Mapping Protocol*. The culmination of your investigation will involve comparing satellite images acquired a few years apart to study land cover change over time by following the *Land Cover Change Detection Protocol*. For the mapping protocols, the final map product is the data reported to GLOBE and this is done at the end of the mapping process. These maps are created to learn more about your surroundings by taking observations and measurements at selected sample locations. Upon completing this investigation, you will know a great deal about the environment surrounding your school and you will be able to monitor change as it happens. For your school, these protocols can last from one day to weeks to months to years. Please refer to the specific section on the *Mapping and Accuracy Assessment Process* for more details.

When are measurements taken?

The best time to take the measurements for the *Land Cover Sample Site* and *Biometry Protocols* is during the peak of the growing season. This is when it is best to assess the land cover class of the site and the full canopy and ground cover. If you are going to visit a site repeatedly and take biometry measurements to monitor changes in biomass over time for a period of years, you can visit the site once every year at the same time of year. Or, if you would like to track changes in biomass throughout the year, you many choose to visit a site twice a year or more, once during the peak of the growing season and once during minimum growth (ex. dry season or winter). The mapping protocols can be performed at any time of year.

Special Considerations

A number of time management, educational, and logistical issues should be considered in deciding how to present and undertake the various *Land Cover/Biology Protocols.*

- Land cover data can be collected from all land cover classes as long as the sites are homogeneous and at least 90 m x 90 m in size.
- Biometry measurements in Land Cover Sample Sites are very useful and offer students a more complete view of the land cover assessment process. They are used to decide the correct land cover class for a Land Cover Sample Site.
- Land Cover Sample Site observations are useful and can be quickly and efficiently collected in sufficient number to validate (or assess the accuracy of) your land cover type map generated from the Landsat Thematic Mapper imagery.
- Students benefit from practicing biometry measurements before going to their Land

Cover Sample Sites. Practice, before going into the field, can lessen the amount of time it takes to collect the observations at the site.

- If a GPS receiver and a camera are available, observation of a Land Cover Sample Site can be accomplished quickly. If they are not, you will have to return to the site to complete the observations. It would be to your benefit to have these with you in the field.
- Schools should collect as many Land Cover Sample Sites as possible for each land cover type present on their land cover type map because many samples are needed to assess the accuracy of the map. Sites collected in different years, by different classes, or even neighboring schools can all be used in the accuracy assessment process.
- Be sure to note the difference between naturally vegetated sites and cultivated sites.
- Review the *Glossary of Terms* to make sure that you understand the terms used throughout this Investigation.

Getting Started

Using the *Land Cover/Biology Protocols,* you and your students can explore the land cover in your GLOBE Study Site and answer questions that are relevant to your particular area, region and/or students. Land cover map creation is just one step for scientists. Once they have created this map, they can use and modify it in order to study a specific question they are researching. For instance, scientists may be studying the habitat of a certain animal or plant, the succession of fields to forests or the rate of growth of a particular village, town or city. They may also be looking at the amount of undeveloped land, how to protect water resources, or where to plant certain crops during the next growing season. Town planners may be interested in creating a map in order to decide new school boundaries, where to connect recreational trails to create one continuous system or how to efficiently run public transportation. These are just some possible uses of your maps. By creating a base map, you and your students have a powerful tool to begin to look at what your students feel is important in their particular area.

There are many ways to begin your investigation of land cover. One of the simplest and quickest is to use the learning activity, *Getting to Know Your Satellite Imagery*. It is an exploration of the imagery. From there, you and your students can begin to notice the "pattern" of land cover in your area. This may bring up community issues that interest your students – water bodies that need protection, land that is being eroded, a trail system that can be connected to other systems, etc. Beginning with these ideas, introduce the protocols as a way to explore these issues further. The student introduction page for each of the protocols offers some questions that your students should be thinking about to be in the correct "mindset" for that protocol. It introduces the kind of data they will be collecting, asks students to think about why they are collecting that particular data, and then asks them how they can apply it to their own questions. By beginning with the learning activity or the protocols themselves, the *Land Cover/Biology Investigation* leaves it to your students to choose what particular part of their environment they want to explore. If your students are hesitant about generating their own questions or do not have an idea where to begin, just collecting the Land Cover Sample Site data and working on the land cover map is a great start, and may help them to come up with their own questions. The *Land Cover Change Detection Protocol* also can serve as a basis for the question: What amount of change has taken place in my GLOBE Study Site between the years of the two images?

Feel free to start with as little or as much data collection as is comfortable. One Land Cover Sample Site is a start. Multiple sites can be collected the next year, once you and your students get accustomed to the process. If you and your students are ready to explore the area surrounding your school, begin the *Land Cover/ Biology Investigation!*

Protocols At A Glance

PROTOCOL	**What procedures are performed?**	**Where are procedures conducted?**	**When are procedures conducted?**	**What equipment is needed?**
Land Cover Sample Site	MUC, latitude, longitude, elevation, photographs	In a 90 m x 90 m homogeneous area	Once for every new site during peak growing season, or more frequently in sites of your choosing	*MUC Field Guide* or *MUC System Table and MUC Glossary of Terms,* GPS, camera, compass, biometry equipment
Biometry	Canopy cover, ground cover, tree, shrub and graminoid height, tree circumference, graminoid biomass	At Land Cover Sample Sites	To determine MUC or to supplement the observations at a site	Densiometer, clinometer, measuring tapes, Vegetation Field Guides, grass clippers, *MUC Field Guide* or *MUC System Table and MUC Glossary of Terms*, GPS, camera, compass
Manual Land Cover Mapping	Manually create a land cover type map	In class, for entire GLOBE Study Site	Once, but may be an iterative process as new sites are added	Landsat TM images, transparencies, markers, *MUC Field Guide* or *MUC System Table* and *MUC Glossary of Terms*
Computer-aided Land Cover Mapping*	Digitally create a land cover type map	On computer, for entire GLOBE Study Site	Once, but may be an iterative process as new sites are added	Computer, Landsat TM data on disk, MultiSpec software, *MUC Field Guide* or *MUC System Table* and *MUC Glossary of Terms*
Change Detection*	Create a land cover change map	On computer, for entire GLOBE Study Site	Once, but may be an iterative process as new sites are added	Computer, Landsat TM data on disk for two different time periods, MultiSpec software

* See the full e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.

Suggested Methodology

The following flow diagrams (Figure LAND-I-3, Figure LAND-I-4) present the methodology to conduct the *Land Cover/Biology Investigation*. The investigation focuses on determining and mapping the land cover for a particular area, the GLOBE Study Site, and monitoring it for changes over time. This flow diagram is divided into two parts. The first part outlines the land cover data collection methods and the second part shows the land cover mapping and change detection procedures. Italics indicate the protocols within the flow diagram. All these measurements can be used to improve our understanding of the cycling of energy, water and chemical elements such as carbon and nitrogen. The land cover maps students make of their GLOBE Study Site and maps of larger areas created by scientists can be used for management, research, and student inquiry. How and where are land cover types changing? Are there differences in soil fertility between the soil under a deciduous forest and a wetland? What happens to the water chemistry when the surrounding land cover changes? These and many other questions are best answered with the help of accurate land cover maps and field measurements.

Data Collection

To begin the *Land Cover/Biology Investigation* you need to become familiar with your GLOBE Study Site by examining the Landsat Thematic Mapper (TM) satellite image and any other maps or photos of the area that you can obtain. Along with examining the imagery, sites on the ground should be explored to begin to understand the various types of land cover within the 15 km x 15 km GLOBE Study Site. Once you gain some familiarity with the GLOBE Study Site, select homogeneous areas (the same land cover type throughout) for collecting Land Cover Sample Site data. Before going to sites, students should have an

Figure LAND-I-3

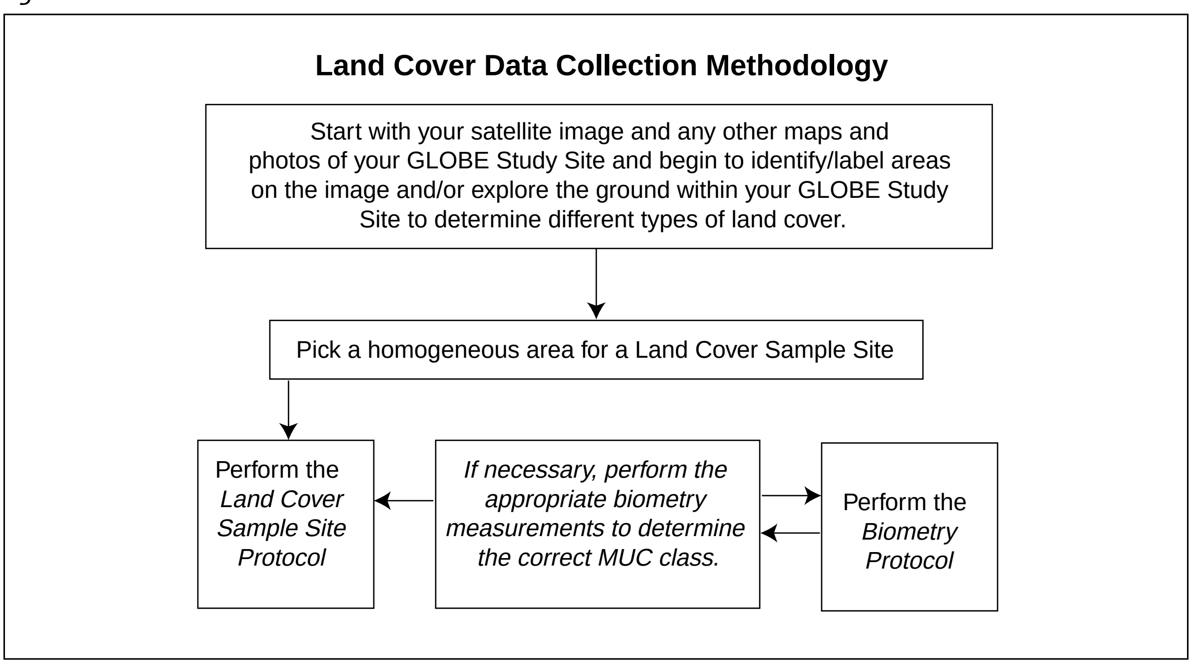
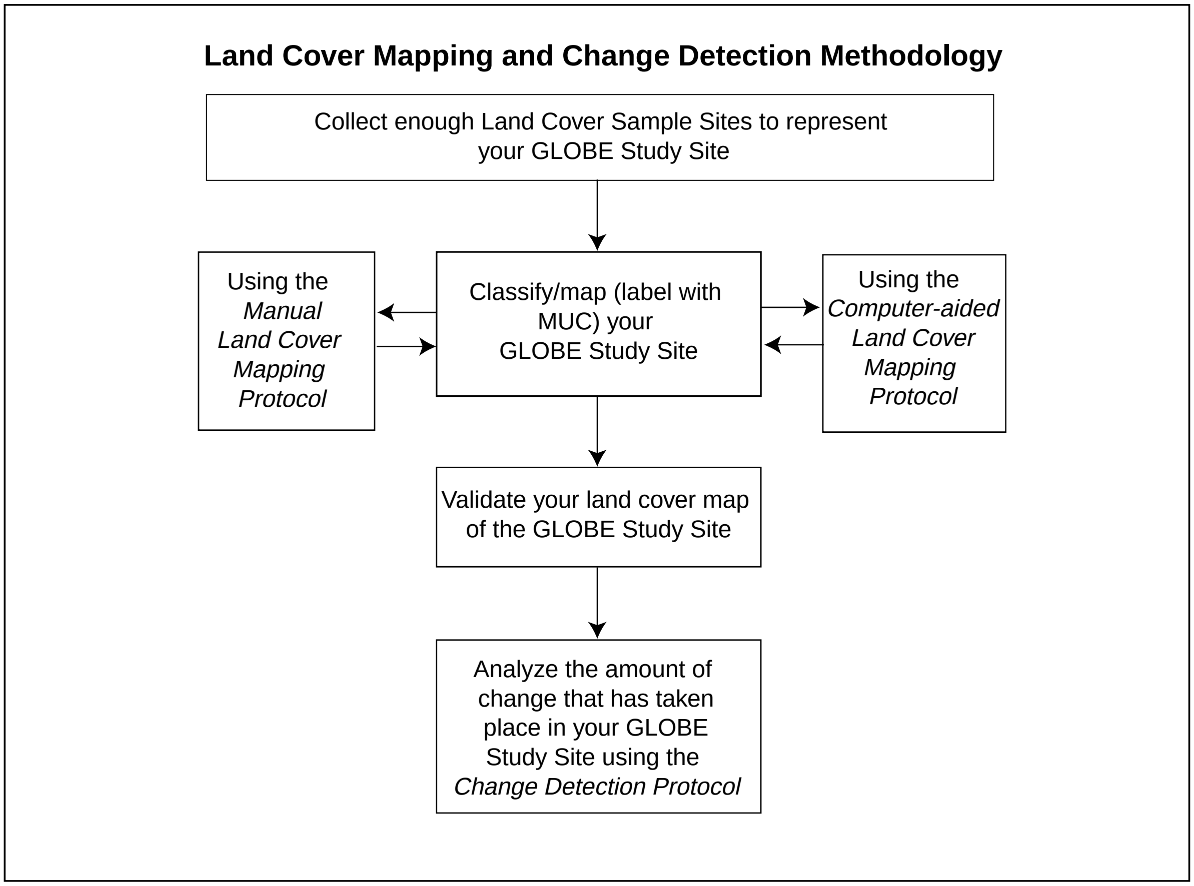


Figure LAND-I-4



understanding of the land cover classification system used in GLOBE, the MUC System, and how the biometry measurements can be used to help determine the MUC class. Also, be sure that you have all the necessary equipment to carry out the field measurements. You will make a few key pieces of equipment yourself following directions in the *Investigation Instruments* section of this chapter. You should also have enough copies of the *Field Guides* for taking the measurements (found in the *Protocols*) and the corresponding *Data Sheets* (found in the *Appendix*). Students who practice the biometry measurements before field collection carry out the measurements more efficiently and accurately in the field. Once a homogeneous sample site has been chosen, the MUC System understood, you have constructed your instruments, made the necessary copies of field guides and *Data Sheets,* and practiced the *Biometry Protocol*, you are ready to establish a Land Cover Sample Site.

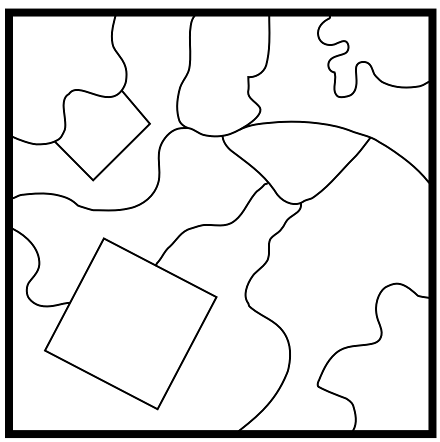
It is highly desirable for you and your students to collect data for several Land Cover Sample Sites in each of the major types of land cover identified within your GLOBE Study Site. You should also collect as much biometry data as needed at each Land Cover Sample Site to accurately classify the site using the MUC System. Start with the most common types of land cover, and continue to add sample sites until you have collected data for as many of the land cover types as you can. Doing this investigation is made easier if your students have a GPS receiver with them when they are at each site. This way, they do not have to return to the site later, find the center and take measurements on another trip.

Biometry data should be collected at Land Cover Sample Sites that are visited once in order to determine the MUC class. The amount of biometry data collected will vary but you can always collect more data to supplement the information about the site. It is desirable to take the full set of biometry measurements at one site that is representative of each forest, woodland and graminoid (grassland) MUC class found in your area. Biometry data can also be collected at sites that you visit more frequently. Some schools choose one site which they visit every year at the same time of year to record changes in biometry over time. Other schools choose to visit a single site twice a year in order to track seasonal changes. Often, their visits will correspond to the times of peak foliage and minimum foliage (drought or winter season). In summary, at a minimum, collect biometry measurements at each site to help you determine the MUC class. The maximum amount of data you collect is your class' decision and should be based on what kind of changes you are monitoring in your site. All land cover data collected accurately by GLOBE students will be useful. GLOBE scientists recognize that logistics and educational concerns will usually dictate what land cover measurements are taken.

Land Cover Sample Sites are important for validating the accuracy of land cover type maps, which is a key scientific objective of this investigation. It is recognized, however, that it will take time, perhaps several successive years, to accumulate a set of Land Cover Sample Sites representative of each important type of land cover within your GLOBE Study Site. You may want to assign a land cover type to each of several student teams, so that no two teams are working in the same type of land cover and as many data are collected as possible.

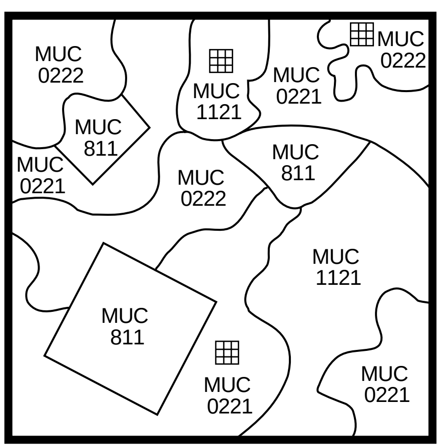
Figure LAND-I-5: Diagram of Accuracy Assessment Process

Step 1: Manual or Computer-aided Land Cover Mapping



The Landsat TM image of your GLOBE Study Site is divided into areas of similar land cover type manually or using MultiSpec.

Step 2: Assign MUC Classes to Areas (Clusters)

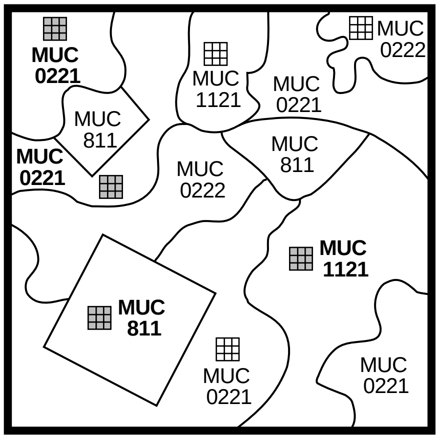


For each area outlined by manual mapping or computer-aided mapping using MultiSpec, assign a MUC class using students' knowledge of the area and data collected from Land Cover Sample Sites.

Land Cover Sample Sites

Figure LAND-I-5: Diagram of Accuracy Assessment Process (continued)

Step 3: Collect Validation Data

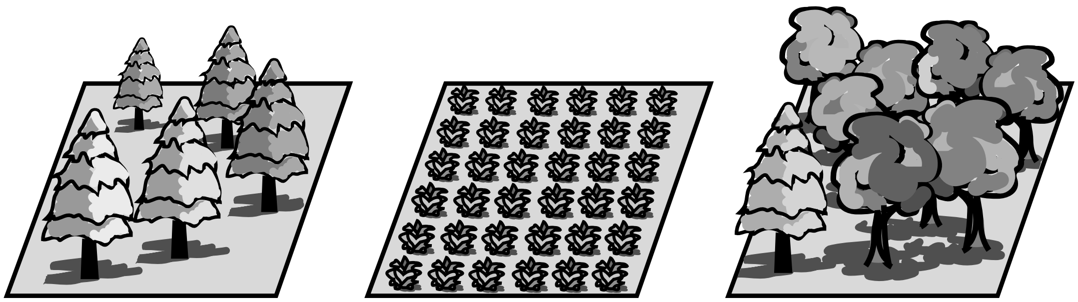


Once the land cover map is made, collect validation data at additional Land Cover Sample Sites to assess the accuracy of the classified map.

Over time, observe and measure as many validation sites as possible for each of the land cover types in your area.

Land Cover Sample Sites

Validation Land Cover Sample Sites



Step 4: Assess Map Accuracy

Validation Data

Student Map Classification	MUC 0221	MUC 0222	MUC 1121	MUC 811	Row Totals
MUC 0221	I				**1**
MUC 0222	I				**1**
MUC 1121			I		**1**
MUC 811				I	**1**
Column Totals	**2**	**0**	**1**	**1**	**4**

Overall Accuracy = 3/4 x 100 = 75%

Compile the data on the Accuracy Assessment Work Sheet and use the Work Sheet to build a difference/error matrix to compare the Student Map Classification data to the Validation Data from Land Cover Sample Sites.

From the difference/error matrix, calculate accuracy assessment percentages to assess how accurate your land cover type map is.

The Mapping and Accuracy Assessment Process

Figures LAND-I-5 show the logical steps in producing a land cover type map and assessing its accuracy. There are two options for creating a map. The first is to create it by hand from prints of your satellite image following the *Manual Land Cover Mapping Protocol*. The second is to create it electronically from a digital version of the satellite image using the MultiSpec software and following the *Computer-aided Land Cover Mapping Protocol*. You are encouraged to begin collecting data for Land Cover Sample Sites before you begin this mapping process. Student observations of individual sites are valuable even if your students do not complete a land cover map of their own because scientists and students in future years or neighboring schools can use your data in their own land cover type maps.

The process is as follows: (1) Collect representative Land Cover Sample Sites of various land cover types. Collect as many of these as you can. Try to collect at least one representative Sample Site for each land cover type that you observe in your Study Site. (2) Create a land cover type map using the MUC System. Use either the *Manual Land Cover Mapping Protocol* and the hard copy prints of the Landsat Thematic Mapper imagery or the *Computer-aided Land Cover Mapping Protocol* with the MultiSpec image processing software and the digital image. Use the sites you collected to assist you in making the map. (3) Collect additional Land Cover Sample Sites. Collect as many of these as you can. (4) Assess the accuracy of your land cover type map by comparing the map you created to the Land Cover Sample Sites collected in your Study Site that students have measured and not used to create their map.

Implementation Considerations

Sequencing, Interconnections, and Interdependence of Learning Activities and Protocols

In order to report data for the main protocol, the *Land Cover Sample Site Protocol*, students must be able to carry out other protocols – the *Biometry Protocol* and the *GPS Protocol*. In addition, students must be able to use MUC to classify land cover, pace accurately, use a compass, and make and know how to use a densiometer and clinometer correctly. It is highly recommended that you use the order below to effectively implement the *Land Cover/Biology Investigation*. Note that *Pre-Protocol Learning Activities* are necessary to ensure that students are familiar with the key concepts and skills required to carry out the protocols.

1	*Getting to Know Your Satellite Imagery* and *GLOBE Study Site Learning Activity*	Investigation Prep, Strongly Recommended
2	*Pacing* and *Compass* (See ***Investigation Instruments***)	Protocol Prep
3	*GPS Protocol* (See *GPS Investigation*)	Imbedded Protocol
4	Make and practice using a *Clinometer* and *Densiometer*, learn how to use and read a *Tape Measure* (See **Investigation Instruments**)	Protocol Prep
5	*Site-Seeing Learning Activity*	Recommended
6	***Biometry Protocol***	Imbedded Protocol
7	*Leaf Classification Learning Activity*	Pre-Protocol, Strongly Recommended
8	Practice with the *MUC System*	Imbedded Skill
9	With the above skills, students should be able to carry out the ***Land Cover Sample Site Protocol.***	
10	*Odyssey of the Eyes Learning Activity*	Pre-Protocol, Strongly Recommended
11	*Manual Classification: A Tutorial for Beverly, MA Image* OR *Introduction to the MultiSpec Program* and the *Unsupervised Clustering Tutorial* (See *MultiSpec CD*)	Protocol Prep, Strongly Recommended
12	After doing at least one *Land Cover Sample Site Protocol*, students should carry out either the ***Manual Land Cover Mapping*** or ***Computer-aided Land Cover Mapping Protocol.***	
13	Collect many more Land Cover Sample Site data	
14	*Bird Beak Accuracy Assessment Learning Activity*	Pre-Protocol, Strongly Recommended
15	**Carry out an *Accuracy Assessment* on their Land Cover Type Maps**	
16	*Change Detection Tutorial*	Protocol Prep, Strongly Recommended
17	***Change Detection Protocol***	Culmination of Investigation
18	*Discovery Area Learning Activity*	Post-Protocol Learning Activity
19	*Using GLOBE Data to Analyze Land Cover Learning Activity*	Post-Protocol Learning Activity